

Incidence of Fat Embolism after Long Fracture Fixation Operations: Review Article

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ABSTRACT

In spite of being rare, fat embolism syndrome is considered a fatal complication after bone fracture and orthopedic procedures. It was suggested that early immobilization might reduce the incidence of fat embolism syndrome. However, no enough data are available to justify this finding. **Objectives:** The aim of this review is to determine the incidence of fat embolism among patients who had long fracture fixation. **Methods:** A systematic review of Medline and Cochrane library was conducted on their database. This search yielded 34 papers, 13 of which were related. **Results:** The incidence of fat embolism syndrome after long fracture fixation ranged from 2.7% and 11%. More specifically, the incidence among long bone fracture patients who were operated early (within the first 24 hours after injury) ranged from zero% in some studies (16,19) to 1.8% in others. As regards late operation, after 24 hour of bone fracture, the incidence of fat embolism syndrome (FES) ranged from 3.5% to 10.4. **Conclusions:** The incidence of fat embolism in post long fracture fixation is very low. Several research works indicate that early fixation significantly reduce the incidence of FES compared to late fixation.

Keywords: Fat Embolism, Long Bone Fracture, Long bone Fixation, Immobilization.

INTRODUCTION

In spite of being rare to happen, fat embolism syndrome (EFS) is a fatal complication that may occur after pelvic or long bone fractures as well as after orthopedic operations⁽¹⁾. It was estimated that the incidence of fat embolism was 0.78% among patients with fracture femur, 0.15% among patients with tibial fractures and 2.4% among patients multiple fractures⁽²⁾. The overall incidence of fat embolism among long-bone fractures was 0.9%^(3,4). Fat embolism syndrome results from the presence of fat in the arterial circulation. The exact mechanism by which the fat emboli reach the arterial circulation remains elusive. It is suggested that a paradoxical embolism process is involved. Fat is thought to traverse from the venous system to an arterial system through a patent foramen ovale or left to right shunts⁽⁵⁻⁷⁾. Three theories were proposed to explain the pathophysiology of fat embolism; the mechanical theory, the free fatty acids lipase theory, and the

coagulation theory. Mechanical theory supposes that fat globules are moved from intramedullary bony cavity after fracture during manipulation due to mechanical pressure gradient, whereas the free fatty acid/lipase theory proposes that the elevation of those chemicals in the blood initiates an inflammatory cascade resulting in vasculitis and systemic manifestations. Coagulation theory, on the other hand, accuse the sluggish circulation encountered in trauma patients of platelet activation that adhere to bone marrow fat. This will eventually initiate a clotting process and thromboembolism⁽⁸⁾.

The classical triad of fat embolism syndrome consists of respiratory manifestations, cerebral symptoms and cutaneous petechiae. Because the diagnosis is sometimes challenging, Wilson proposed diagnostic criteria for fat embolism. The criteria include 3 major, 5 minors, and 2 laboratory criteria (shown in table 1). The diagnosis of fat embolism

syndrome can be assumed in the presence of 1 major criterion, 4 minor criteria, and fat macro globules in urine⁽⁵⁾.

Table (1): Fat embolism diagnostic criteria according to Gurdand Wilson⁽⁵⁾

Major	Petechia
	Respiratory symptoms
	Neurological symptoms
Minor	Tachycardia (> 120 / min)
	Fever (> 39.4 ° C)
	Eye background with fat film / petechia
	jaundice
	Anuria / oliguria
Laboratory	Thrombocytopenia (> 150,000)
	Fat macro globules in urine
	Increased blood flow rate (> 71 mm / h)

Cutaneous petechiae occur specifically in skin folds of axilla and neck, in mucous membranes and in conjunctiva. In spite of occurring late – it is usually the last element of the triad to present-, it is usually pathognomonic for fat embolism syndrome. Cutaneous manifestations are thought to occur due to occlusion of dermal capillaries by fat globules leading to extravasation of blood resulting in petechial cutaneous hemorrhages. Respiratory manifestations may include dyspnea, tachypnea, or hypoxemia that occur 12-24 hours after bone fracture. Chest radiographs show diffuse patchy infiltrations. It is estimated that up to 50% of fat embolism syndrome need mechanical ventilation. Cerebral manifestations include confusion, clouding of consciousness, seizures, and even coma. Cerebral involvement often occur concomitant with respiratory involvement^(4,5,9,10).

Diagnosis of fat embolism syndrome is mainly clinical. Even though, laboratory as well as radiological investigations aid in confirming the diagnosis. Chest X ray showing patchy infiltrations, lung atelectasis, and/or alveolar hemorrhage. The identification of fat lobules in urine or sputum supports the diagnosis⁽⁵⁾.

There is no definitive treatment for fat embolism syndrome, and supportive measures are the mainstay of management. Mortality rates from fat embolism is high ranging from 5 – 10%^(11,12).

The incidence of fat embolism syndrome is generally low ranging from 2-5%⁽¹⁾. It is suggested that early fixation and immobilization of fractures reduce the incidence of fat embolism syndrome

(FES)⁽⁷⁾. Early immobilization is thought to minimize the inflammation as well as the general hypovolemic state of the patient. However, a number of cases were reported to have fat embolism even after early fixation of their long bones fractures⁽¹³⁾. The aim of this review was to determine the incidence and prevalence of fat embolism after fixation of long bone fracture among different reported studies to provide a quantitative evidence on the impact of early fixation and embolization on the occurrence fat embolism.

METHODS

To conduct this review, a systematic review was performed on an online database, namely PubMed and Cochrane Library. PubMed search yielded 34 results; whereas Cochrane Library yielded 9 results. We inspected deeply the collected results and selected the appropriating significant results. Of the 34 results, 13 studies were of specific correlation with our objectives. We included results of studies which were concerned with the incidence and/or prevalence incidence and/or prevalence of fat embolism among patients who had long bone fractures and were operated. The research studies which reported fat embolism among patients with pelvis, vertebral or other non-long bone fracture were excluded. Similarly, studies which focusing on the general incidence general incidence among trauma patients, i.e. without specifying the role of fixation or early immobilization, were excluded. Among the 13 studies, 5 were case reports, 1 was randomized controlled trial, and 7 were prospective or retrospective studies.

The study was done after approval of ethical board of King Abdulaziz university.

RESULTS

Data collected from the 8 selected articles are illustrated in Table 1. In 2002, **Ron van Doorn et al.** conducted a retrospective study in Netherland on 101 patients with pathological femur fracture to determine the impact of fixation with a long Gamma nail on the outcome of fracture. Results from their review stated that only 3 out of 101 patients operated with long Gamma nails⁽¹⁴⁾. **Pape et al.**⁽¹⁵⁾ studied 766 patients retrospectively to determine the effect of early versus late intramedullary fixation of long fractures on the outcome of the disease and pulmonary complications. It was concluded in this study that the early fixation was beneficial in decreasing pulmonary complications as well as fat embolism syndrome only in patients without sever chest involvement.

Table (2): Review of literature survey indicating the incidence of fat embolism after long bone fixation

No.	Date	Author	Patients number	Type of study	Bone fracture	Incidence of fat embolism reported
1	2000	• Doom <i>et al.</i> ⁽¹⁴⁾	101	Retrospective	Femur pathological fracture	3 in 101 patients developed fat embolism after fixation
2	1988	• Pinney <i>et al.</i> ⁽¹⁶⁾	274	Retrospective	Isolated femoral fracture	0% in patients with early fixation, and 10% in patients with delayed fixation (P<0.07)
3	1993	Pape <i>et al.</i> ⁽¹⁵⁾	766	Retrospective	Different fractures	Early intramedullary nail fixation was beneficial and decreased the incidence of FES and other complications in patients without severe chest trauma.
4	1990	Fabian <i>et al.</i> ⁽¹⁷⁾	92	Prospective 12 months	long bone or pelvic fracture (LBPF)	The incidence of FES was 11%
5	1989	Bone <i>et al.</i> ⁽¹⁸⁾	178	Prospective randomized controlled trial	femoral fractures	Delayed stabilization of bone fracture significantly increased FES and other pulmonary complications.
6	1988	Ten Duis <i>et al.</i> ⁽¹⁹⁾	2 groups	Retrospective	Isolated femoral shaft fracture	Fat embolism occurred in 3.5% of patients (only in non-decompressed group of patients) None of operated patients had fat embolism.
7	1986	Lozman <i>et al.</i> ⁽⁸⁾	18	Prospective	Long bones fracture	Immediate fixation had less pulmonary complications than delayed fixation
8	1980	Svenningsen <i>et al.</i> ⁽²⁰⁾	220	Retrospective	Femoral fractures	10.4% in late fixation 1.8% in early fixation

In a prospective study held in 1990, **Bone *et al.*** reported that the incidence of fat embolism syndrome (FES) among 92 patients with long bone fracture who were operated was 11%⁽¹⁷⁾. A prospective randomized controlled trial conducted in 1989 on 178 patients on femoral fractures reported that early stabilization of femoral fractures had significantly decreased fat embolization, as well as other pulmonary complications such as adult respiratory-distress syndrome and pneumonia⁽¹⁸⁾. Similarly, a prospective study held on 18 patients with long bone fracture stated that immediate fixation

had significantly reduced pulmonary complications (including fat embolism) than delayed fixation⁽⁸⁾. Furthermore, a study carried out on 274 patients with isolated femoral shaft fractures in 1998 revealed that 11 patients (4%) developed fat embolism syndrome. Sixty of the 247 patients were early operated (within 24 hours of insult) and none of them developed fat embolism, whereas, among the 109 patients whose operation was delayed to more than 24 hours, fat embolism occurred in 10%. The difference between the 2 groups was statistically significant (p<0.027)⁽¹⁶⁾.

In 1988, a retrospective study was held on patients with an 'isolated' fracture of the femoral shaft who had been operated within 24 hours after fracture (decompression group), and those who had been treated only conservatively (non-decompression group). Researchers indicated that fat embolism occurred only in patients in the non-decompressed group (3.5%)⁽¹⁹⁾.

Svennningsen et al.⁽²⁰⁾ conducted a study in 1980 on 220 patients with femoral fractures to explore the impact of early versus late fixation on the prevention of fat embolism among patients. They stated that the incidence of fat embolism in patients who had an early fixation of their femur fractures was 1.8%, whereas the incidence among those who had delayed fixation was significantly higher, with a figure of (10.4%).

Furthermore 5 case reports indicated that fat embolism might still occur even after early fixation. In 2009, **Kleinert et al.**⁽¹³⁾ reported 2 cases, aged 20 and 27 year-old, who had a rapid fixation of their lower limb fracture. However, they developed fat embolism syndrome (FES). Similarly, multiple cases were reported in the literatures who had fat embolism syndrome in spite of immediate fixation of their long fracture⁽²¹⁻²⁴⁾.

DISCUSSION

Fat embolism is not uncommon among trauma patients⁽²⁵⁾, however, the incidence of fat embolism among patients with long-bone fractures is low, ranging from 2-5%⁽¹⁾. Fixation of these fractures was reported to significantly decrease the incidence of fat embolism syndrome^(7,13). The aim of this review was to explore the incidence and prevalence of fat embolism syndrome after long fracture fixation. It is noteworthy to indicate that few studies in the search data base were available (Medline and Cochrane Library) which indicated solid prevalence for fat embolism after surgical fixation of long bone fracture. As regards the incidence, it was obvious from the few studies available that early fixation of long bone fractures had a significant beneficial impact on the reduction of fat embolism syndrome associated with these fractures. Moreover, Many research studies stated that early stabilization of long bone fractures had significantly decreased fat embolization and pulmonary complications such as adult respiratory-distress syndrome and

pneumonia^(8,16,18-20). The timing of fixation of long bone fracture seemed to be a major contributor to the outcome⁽²⁶⁾. Furthermore, **Korhan et al.**⁽⁴⁾ in their review article reported that early surgical fixation and immobilization of long fractures had reduced the incidence of pulmonary complications significantly. Overall, the incidence of fat embolism syndrome after long fracture fixation ranged from 2.7%⁽¹⁴⁾ and 11%⁽¹⁷⁾. More specifically, the incidence among long bone fracture patients who were operated early (within the first 24 hours after injury) ranged from zero% in some studies^(16,19) to 1.8% in others⁽²⁰⁾. As regards late operation, after 24 hour of bone fracture, the incidence of fat embolism syndrome (FES) ranged from 3.5% to 10.4%^(16,19,20).

It seems that early fixation of long bone fracture plays a major role in reducing the release of fat globules, fatty acids, and lipase to the circulation and consequently reducing the symptoms and complications of fat embolism syndrome. Reduction of movement seems to be critical for minimizing fat embolization. Although the exact mechanism by early fixation would reduce fat embolism is still elusive, a proposed mechanism could be the reduction of inflammatory response to released fat and fatty acids and eventually stabilization of the capillary walls. More recently, surgical techniques were developed to target other mechanisms of fat embolism, particularly the mechanical theory. Novel surgical techniques were developed to reduce the raised intraosseous pressure through using unreamed nails, sharp reamers, or hollow nails to allow some sort of ventilation to the medullary cavity⁽¹²⁾.

Although there is unavailable consensus regarding the importance of early fixation of long bone fracture, it is obvious that early immobilization of fractures has a significant beneficial impact on reduction of fat embolism syndrome among these patients.

CONCLUSION

The incidence of fat embolism after long bone fracture is very low. Early fixation and immobilization of long bones after fracture significantly reduced the incidence of fat embolism syndrome (FES) when compared to late fixation. Early fixation is thus recommended during the first 24 hours of long bone fracture. The exact pathophysiology of the beneficial effect of early

immobilization remains elusive, however, reduction of inflammatory response to released fat globules and fatty acids to circulation is a proposed mechanism.

REFERENCES

1. **Habashi NM, Andrews PL, Scalea TM (2006):** Therapeutic aspects of fat embolism syndrome. *Injury*,37(4):68–73.
2. **Tsai IT, Hsu CJ, Chen YH, Fong YC, Hsu HC, Tsai CH (2010):** Fat embolism syndrome in long bone fracture-clinical experience in a tertiary referral center in Taiwan. *J Chinese Med Assoc*, 73(8):407–10.
3. **Caplan LR, Caplan LR (2009):** Brain Embolism. In: Caplan's Stroke [Internet]. Available from: <http://linkinghub.elsevier.com/retrieve/pii/B9781416047216500110>
4. **Taviloglu K, Yanar H (2007):** Fat embolism syndrome. *Surg Today*, 37(1):5–8.
5. **Mellor A, Soni N (2001):** Fat embolism. *Anaesthesia*, 56(2):145–54.
6. **Godoy DA, Napoli M Di, Rabinstein AA (2008):** Cerebral Fat Embolism: Recognition, Complications, and Prognosis. *Neurocrit Care*. Available from: <https://link.springer.com/article/10.1007%2Fs12028-017-0463-y>
7. **Pell ACH, Hughes D, Keating J, Christie J, Busuttil A, Sutherland GR (1993):** Fulminating Fat Embolism Syndrome Caused by Paradoxical Embolism through a Patent Foramen Ovale. *The New England journal of medicine*, 329(13):926–9.
8. **Lozman J, Deno DC *et al.* (1986):** Pulmonary and cardiovascular consequences of immediate fixation or conservative management of long-bone fractures, 121(9):992–9
9. **Kearsley R, Galbraith J, Dalton D, Motherway C (2016):** Spinal cord infarction as a rare complication of fat embolism syndrome following bilateral intramedullary nailing of femur fractures. *BMJ Case Rep*; bcr 215690. Available from: <http://www.ncbi.nlm.nih.gov/pubmed/27624445>
10. **Kwiatt ME, Seamon MJ (2013):** Fat embolism syndrome. *Int J Crit Illn Inj Sci*. Wolters Kluwer -- Medknow Publications,3(1):64–8.
11. **Fulde GW, Harrison P (1991):** Fat embolism—a review. *Arch Emerg Med*. BMJ Publishing Group,8(4):233–9.
12. **Bhalla T, Sawardekar A, Klingele K, Tobias JD (2011):** Postoperative hypoxemia due to fat embolism. *Saudi J Anaesth*. Wolters Kluwer -- Medknow Publications,5(3):332–4.
13. **Kleinert K, Marug D, Soklic P, Simmen HP (2009):** Fettemboliesyndrom nach Unterschenkelfraktur trotz sofortiger Versorgung mit einem Fixateur externe : Zwei Kasuistiken und Literaturübersicht. *Unfallchirurg*, 112(9):796–8.
14. **Van Doorn R, Stapert JW (2000):** Treatment of impending and actual pathological femoral fractures with the long Gamma nail in The Netherlands. *Eur J Surg*, 166(3):247–54.
15. **Pape HC, Paffrath T *et al.* (1993):** Primary intramedullary femur fixation in multiple trauma patients with associated lung contusion--a cause of posttraumatic ARDS? *J Trauma*, 34(4):540–7–8.
16. **Pinney SJ, Keating JF, Meek RN (1998):** Fat embolism syndrome in isolated femoral fractures: does timing of nailing influence incidence? *Injury*, 29(2):131–3.
17. **Fabian TC, Hoots A V *et al.* (1990):** Fat embolism syndrome: prospective evaluation in 92 fracture patients. *Crit Care Med*, 18(1):42–6.
18. **Bone LB, Johnson KD, Weigelt J, Scheinberg R (1989):** Early versus delayed stabilization of femoral fractures. A prospective randomized study. *J Bone Joint Surg Am*, 71(3):336–40.
19. **Ten Duis HJ, Nijsten MW, Klasen HJ, Binnendijk B (1988):** Fat embolism in patients with an isolated fracture of the femoral shaft. *J Trauma*, 28(3):383–90.
20. **Svenningsen S, Nesse O, Finsen V, Hole A, Benum P (1987):** Prevention of fat embolism syndrome in patients with femoral fractures--immediate or delayed operative fixation? *Ann Chir Gynaecol*, 76(3):163–6.
21. **Akoh CC, Schick C, Otero J, Karam M (2014):** Fat embolism syndrome after femur fracture fixation: a case report. *Iowa Orthop J*, 34:55–62.
22. **Powers KA, Talbot LA (2011):** Fat Embolism Syndrome After Femur Fracture With Intramedullary Nailing: Case Report. *Am J Crit Care*, 20(3):267–266.
23. **Sudulagunta SR, Kumbhat M *et al* (2016):** Fat Embolism Syndrome: Case Report. *J Neurol Res*, 6(5–6):114–7.
24. **DeFroda SF, Klinge SA (2016):** Fat Embolism Syndrome With Cerebral Fat Embolism Associated With Long-Bone Fracture. *Am J Orthop (Belle Mead NJ)*, 45(7):E515–21.
25. **Constantine S Bulautian VLR (2017):** Fat Embolism: Background, Pathophysiology, Etiology. Available from: <http://emedicine.medscape.com/article/460524-overview#a8>
26. **Blokhus TJ, Pape HC, Frölke JP (2017):** Timing of definitive fixation of major long bone fractures: Can fat embolism syndrome be prevented? *Injury*, 48 (1):S3–s6.